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Influence of Bos indicus crossbreeding and cattle age on apparent utilization of a high-grain diet

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Influence of *Bos indicus* crossbreeding and cattle age on apparent utilization of a high-grain diet[1,2]

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ABSTRACT: Ten *Bos indicus* × MARC III (initial BW = 303 ± 25 kg) and 10 MARC III (initial BW = 322 ± 16 kg) steers were used in a 2 × 2 factorial design to determine whether cattle age or *Bos indicus* crossbreeding influence site of digestion of a high-grain diet. Initially, five *Bos indicus* × MARC III and five MARC III steers were fitted with duodenal cannulas and adapted to a 95% concentrate diet that was offered for ad libitum consumption for a 237-d feeding period (calves). During the feeding period, duodenal and fecal samples were collected during 4-d periods beginning on d 14, 67, 137, and 228. The remaining 10 steers were fed a forage-based diet for a targeted daily gain of .6 to .7 kg for 210 d (yearlings). Following this period, yearling steers were duodenally cannulated and adapted to the 95% concentrate diet. Yearling steers had ad libitum access to feed for 165 d, and samples were collected during 4-d periods beginning on d 13, 42, 102, and 159. Dry matter intake was 9.8 and 7.6 kg/d and daily gain was 1.35 and 1.16 kg in yearlings and calves, respectively. Apparent OM digestion in the stomach was greater (P < .01) in yearlings than in calves. In contrast, postruminal disappearance as a percentage of OM intake was greater (P = .05) in calves than in yearlings. Duodenal flows of total N, microbial N, nonmicrobial N, and total amino acids and total tract N digestibility were not affected (P > .05) by age or *Bos indicus* crossbreeding. Fecal N excretion was greater (P < .01) in yearlings than in calves. Results of this experiment suggest little effect of *Bos indicus* influence on utilization of a high-grain diet. However, more feed is digested in the rumen of yearlings than of calves consuming a high-grain diet.

Key Words: *Bos indicus*, Calves, Feedlot, Yearlings

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Introduction

Bos indicus and *Bos indicus* crossbred cattle utilize low quality forage diets more efficiently than *Bos taurus* cattle (Ashton, 1962; Karue et al., 1972). Improved utilization of low-quality forage might result from lower maintenance requirements by *Bos indicus* vs *Bos taurus* in nutritionally restrictive environments (Frisch and Vercoe, 1977). In contrast, when high-quality forage (21% CP; Moran, 1976) or forage plus concentrate (Ledger et al., 1970; O'Donovan et al., 1978) diets are fed, *Bos taurus* cattle consume more feed relative to their maintenance energy requirements, thereby gaining faster and more efficiently than *Bos indicus* cattle. Similarly, Beaver et al. (1989) reported that Angus steers consumed more feed and gained faster but had similar diet digestibility and feed efficiency compared with Brangus steers when fed an 87.5% concentrate diet.

The effect of age on utilization of a high-grain diet has been studied less extensively. Sindt et al. (1991) reported that when exposed to high-grain feeding, yearling cattle consume more feed (percentage of BW) and gain faster but are less efficient than calves. Because of differences in feed intake, one might expect differences in diet utilization to occur as well. Subtle differences in total tract digestion often correlate to large differences in ruminal vs postruminal digestion when cattle are fed high-grain diets (Axe et al., 1987). Moreover, the potential for lower feed intake by *Bos indicus* species in combination with the effect of age on intake may reduce performance in *Bos indicus* calves compared with yearlings. However, the interaction between age and biological type on diet utilization has not been elucidated in cattle that consume a high-grain diet. Therefore, the objective of this experiment was to determine whether age or *Bos indicus* crossbreeding influ-

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Table 1. Composition of the diet (DM basis) fed to *Bos indicus* × MARC III and MARC III calves and yearlings

Ingredient	Percentage of diet
Dry-rolled corn	86.73
Chopped alfalfa hay[a]	5.0
Soybean oil	3.0
Soybean meal, (44%CP)	2.0
Urea	1.0
Limestone	1.0
Potassium chloride	.5
Sodium chloride	.3
Dicalcium phosphate	.3
Cattle trace mineral[b]	.05
Vitamin ADE premix[c]	.05
Vitamin E premix	.05
Rumensin premix[d]	.02

[a]Chopped to pass through a 13-cm screen.
[b]Trace mineral premix consisted of 13% Ca, 12% Zn, 8% Mn, 10% Fe, 1.5% Cu, .2% I, and .1% Co.
[c]Vitamin premix contained 8,800,000 IU of vitamin A; 880,000 IU of vitamin D; and 880 ppm of vitamin E/kg.
[d]132 g of monensin/kg of premix (Elanco Animal Health, Indianapolis, IN).

ence site of digestion when these cattle are fed a high-grain diet.

Materials and Methods

Animals and Location. Five Boran × Meat Animal Research Center (MARC) III (1/4 Angus, Hereford, Pinzgauer, and Red Poll) steers (initial BW = 301 ± 20 kg) and five Brahman × MARC III steers (initial BW = 305 ± 29 kg) were selected from the germ plasm evaluation herd at MARC. In addition, 10 MARC III steers (initial BW = 322 ± 16 kg) were selected that were similar in age and weight to the Boran and Brahman cross steers. Range in birth date for steers used in the experiment was from March 31, 1992, to May 12, 1992. These 20 steers were placed in metabolism stalls and gentled for approximately 2 wk. During this time, steers were fed a growing diet to limit gain to approximately .6 to .7 kg/d. Experimental procedures were conducted in accordance with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Consortium, 1988). Protocols were approved by the U.S. Meat Animal Research Center's Animal Care and Use Committee.

Experimental Design, Surgery, and Feeding. The design was completely random with the comparisons of calves vs yearlings and *Bos indicus* × MARC III vs MARC III. After steers were sufficiently gentled, three Boran × MARC III, two Brahman × MARC III, and five MARC III steers were surgically fitted with duodenal cannulas (Rupp et al., 1994). After surgery, steers were placed individually in open lot pens. Pens had concrete flooring and were 3.5 m wide and 20 m long, and a roof covered the front third of each pen. Steers were adjusted to a 95% concentrate diet (Table 1) that was fed for ad libitum consumption for a 237-d feeding period. Calves were fed from February 5, 1993, through September 30, 1993. Orts were weighed daily throughout the entire feeding period to determine DMI. Four times during the feeding period, steers were moved to a metabolism barn for 4-d collection periods beginning on d 14, 67, 137, and 228. The metabolism stalls were 1 m wide and 2 m long and were fitted with rubber mats. The barn had continuous lighting and mechanical ventilation. Steers were trained to this routine such that feed intake in the metabolism barn was similar to feed intake in the open lot pen.

Steers not fitted with a duodenal cannula were pen fed as a group for approximately 210 d (to achieve age differences). Steers were fed a forage-based diet for a targeted daily gain of .6 to .7 kg/d. This diet was predominantly corn silage (84.8%, DM basis) and was formulated to contain 2.69 Mcal/kg of ME, 12.9% CP, .74% Ca, and .36% P (DM basis). After approximately 210 d, when steers weighed between 360 and 400 kg, two Boran × MARC III, three Brahman × MARC III, and five MARC III steers were re-gentled and fitted with duodenal cannulas as described previously. Following surgery, steers were adapted to the 95% concentrate diet and managed similarly to the previous group, with two exceptions. First, yearlings were fed for 165 d from August 19, 1993, through January 31, 1994. Second, because of expected fewer days on feed, the 4-d collection periods began on d 13, 42, 102, and 159 of the feeding period.

Sampling and Laboratory Analyses. Chromic oxide was mixed with dried molasses (7.5% chromic oxide:92.5% dried molasses) and 200 g was top-dressed so that each steer received 15 g of chromic oxide/d. This was used as a digesta flow marker. During the sampling periods, duodenal digesta were collected (approximately 150 g) three times daily (0700, 1400, and 2100) for three consecutive days. Fecal grab samples were collected (150 g) once daily for four consecutive days. Duodenal and fecal samples were stored frozen (−20°C), and then lyophilized, ground in a blender (60 s at maximum speed), composited (weight basis), and analyzed for DM, N, and ash by standard procedures (AOAC, 1990) and for Cr by the method of Williams et al. (1962). In addition, duodenal samples were analyzed for purines by the procedures of Ushida et al. (1985) and Zinn and Owens (1986). Amino acids in acid-hydrolyzed (6 *N* HCl; AOAC, 1990) duodenal contents were separated by high-performance liquid chromatography using a lithium ion-exchange column (Pickering Laboratories, Mountain View, CA) followed by post-column derivatization.

At slaughter, ruminal digesta were collected to harvest bacterial cells. Twelve hundred grams of ruminal digesta was combined with an equal amount of saline (.9% wt:wt) and frozen. Samples were thawed at room temperature, blended for 1 min in a Waring blender at maximum speed, passed through four layers of cheesecloth, and centrifuged at 500 × *g* for 5 min (two times) to remove feed particles and protozoa. Bacteria were

Table 2. Performance and carcass characteristics in *Bos indicus* × MARC III and MARC III calves and yearlings consuming a high grain diet

	Bos indicus × MARC III		MARC III			Probability[a]		
Item	Calves	Yearlings	Calves	Yearlings	SEM	Type	Age	T × A
Initial BW, kg	299	388	322	382	9	.35	<.01	.15
Final BW, kg	551	598	589	586	19	.50	.26	.20
Daily gain, kg	1.12	1.37	1.19	1.32	.08	.87	.03	.47
DM intake, kg/d	7.1	10.0	8.1	9.5	.3	.62	<.01	.15
Grain/feed	.158	.138	.147	.140	.009	.42	.03	.25
Hot carcass wt, kg	338	367	368	358	12	.39	.42	.13
Marbling[b]	410	260	290	360	52	.85	.46	.06
Fat thickness, cm	2.18	1.60	2.24	1.35	.31	.76	.03	.61
Loin eye area, cm^2	29.9	29.7	27.4	29.9	1.3	.39	.37	.30
KPH, %[c]	3.63	3.63	3.88	3.00	.36	.61	.24	.24
Quality grade[d]	20.5	17.3	21.5	19.0	.55	.03	<.01	.51
Yield grade	4.5	4.0	5.2	3.6	.44	.70	.03	.23

[a]Probability corresponding to the hypothesis of no effect of biological type (T), age (A), or their interaction (T × A).
[b]Slight 0 = 200, small 0 = 300, moderate 0 = 400, etc.
[c]Kidney, pelvic, and heart fat as a percentage of carcass weight.
[d]High Select = 18, low Choice = 19, average Choice = 20, high Choice = 21, low Prime = 22, etc.

then separated from the supernatant by centrifuging for 20 min at 20,000 × *g*. The pellet was washed with .9% NaCl, recentrifuged (20,000 × *g*), and rinsed with distilled water. The resulting bacterial suspension was freeze-dried, and N and purines were determined as described previously.

Carcass measurements taken at slaughter included hot carcass weight (**HCW**); percentage kidney, pelvic, and heart fat (**KPH**); 12th rib fat thickness; marbling score; yield grade; and quality grade.

Calculations and Statistics. Stomach and poststomach digestibilities were estimated using the marker ratio technique (Merchen, 1988) with Cr as the reference. Duodenal bacterial N flows were determined by using purines as a microbial marker (Zinn and Owens, 1986).

For all response variables measured, the initial model included breed to test for differences between Boran × MARC III and Brahman × MARC III steers. When a nonsignificant ($P > .05$) F-test for breed was detected, the model compared *Bos indicus* × MARC III vs MARC III. Data on performance and carcass characteristics were analyzed as a completely randomized design using GLM procedures of SAS (1990). The model included age, biological type, and the age × biological type interaction. Data on intake and site and extent of digestion were analyzed as a split plot. The model included those terms just described, age × biological type (nested within animal), sampling day, sampling day × age, sampling day × biological type, and sampling day × age × biological type. Mean squares due to age × biological type nested within animal were used to test the significance of age, biological type, and the age × biological type interaction. Significance of sampling day and its interactions were tested with residual mean squares of the split-plot model. Due to unequal sampling days and intervals between sampling days for calves and yearlings, significant ($P < .05$) sampling day × age × biological type or sampling day × age interactions resulted in data being sorted by age and reanalyzed as a split-plot as described above. The model included biological type and its interaction with sampling day. Results were considered significant at the $P < .05$ level.

Results and Discussion

The number of observations for MARC III and *Bos indicus* × MARC III calves was four due to problems unrelated to treatments. By design, initial BW for the high-grain finishing period was greater ($P < .01$) for yearlings (385 kg) than for calves (311 kg), but final BW were similar ($P > .05$; Table 2). Biological type did not affect ($P > .05$) daily gain, DMI, or gain:feed ratio. Similar to our experiment, Boyles and Riley (1991) found no difference in ADG or feed:gain in Angus vs Brahman × Angus steers consuming an 85% concentrate diet, and Kappel et al. (1972) and Young et al. (1978) reported no significant difference in feedlot performance among British and Zebu breed types. In contrast, other research demonstrated that greater DMI (Beaver et al., 1989; Huffman et al., 1990) and ADG (Adams et al., 1982; Carroll et al., 1955; Beaver et al., 1989) were achieved in British type cattle compared to *Bos indicus*-cross cattle consuming a high-grain diet. Reasons for discrepancies between experiments are uncertain but may relate to breed differences and(or) level of concentrate fed.

In our experiment, yearling steers ate 28% more feed ($P < .01$), gained 16% more weight ($P = .03$), and were 10% less efficient ($P = .03$) than calves. Sindt et al. (1991) summarized five years of data comparing performance of cattle finished as yearlings or as calves. Similar to our results, the authors reported that calves consumed less feed and gained more slowly, but gained more per kilogram of feed consumed than yearlings. Similarly, Frahm and Stanforth (1975) and Dikeman et al. (1985) reported that calves were more efficient at converting feed to gain during the finishing phase than were yearlings that had been in a backgrounding program from weaning to entering the feedlot. In the experiment of Huffman et al. (1990), yearlings entered the feedlot heavier than calves and had heavier slaughter weights than calves placed directly in the feedlot. Calves were fed longer and had lower ADG than yearlings. These data indicate that gain per kilogram of feed consumed is greater when cattle are fed at an earlier age and that *Bos indicus* crossbreeding does not affect feedlot performance.

In our experiment, HCW, marbling score, loin eye area, and KPH were not affected ($P > .05$) by age or biological type (Table 2). However, quality grade was greater ($P = .03$) in MARC III steers than in *Bos indicus* × MARC III steers. Numerous researchers have reported lower marbling scores and quality grades when straightbred Brahman or Brahman crossbreds were compared to cattle of predominantly *Bos indicus* breeding (Cole et al., 1963; Adams et al., 1982; Koch et al., 1982). In the study of Boyles and Riley (1991), more Angus steers than Brahman × Angus steers graded choice. This is similar to our experiment.

Sindt et al. (1991) reported greater fat over the 12th rib and a higher percentage of Choice carcasses in calves than in yearlings. In our experiment, fat thickness ($P = .03$), quality grade ($P < .01$), and yield grade ($P < .01$) were greater in calves than in yearlings at the same BW end point, which is similar to the data of Sindt et al. (1991). These data are also in agreement with Lunt and Orme (1987), who suggested that cattle fed grain from weaning to slaughter need to be slaughtered when lighter than cattle initially fed forage to have the same carcass composition at slaughter.

Intake variables (i.e., DM, OM, and N) responded with sampling day × age interactions ($P < .01$). Dry matter intake for the sampling periods is shown in Figure 1. Within age, no effects ($P > .05$) of *Bos indicus* biological type were observed; however, a sampling day × type interaction ($P < .01$) was observed for calves. This interaction resulted because DMI in *Bos indicus* crossbred calves was continuing to increase throughout the 237-d feeding period, whereas DMI in MARC III calves increased to d 140 and then decreased at 231 d. Intakes of OM and N followed a similar pattern (data not shown).

Duodenal OM flow ($P = .03$) and postruminal OM digestion ($P = .02$) were greater in Brahman × MARC III steers (2,841 ± 137 and 1,793 ± 130 g/d) than in Boran × MARC III (2,054 ± 109 and 1,037 ± 103 g/d) and MARC III (2,260 ± 90 and 1,179 ± 85) steers, respectively. Duodenal OM flow and site of digestion did not respond ($P > .05$) with sampling day × age × biological type or sampling day × biological type interactions. Therefore, age was included in the model, and the whole-plot main effects are shown (Table 3). Apparent

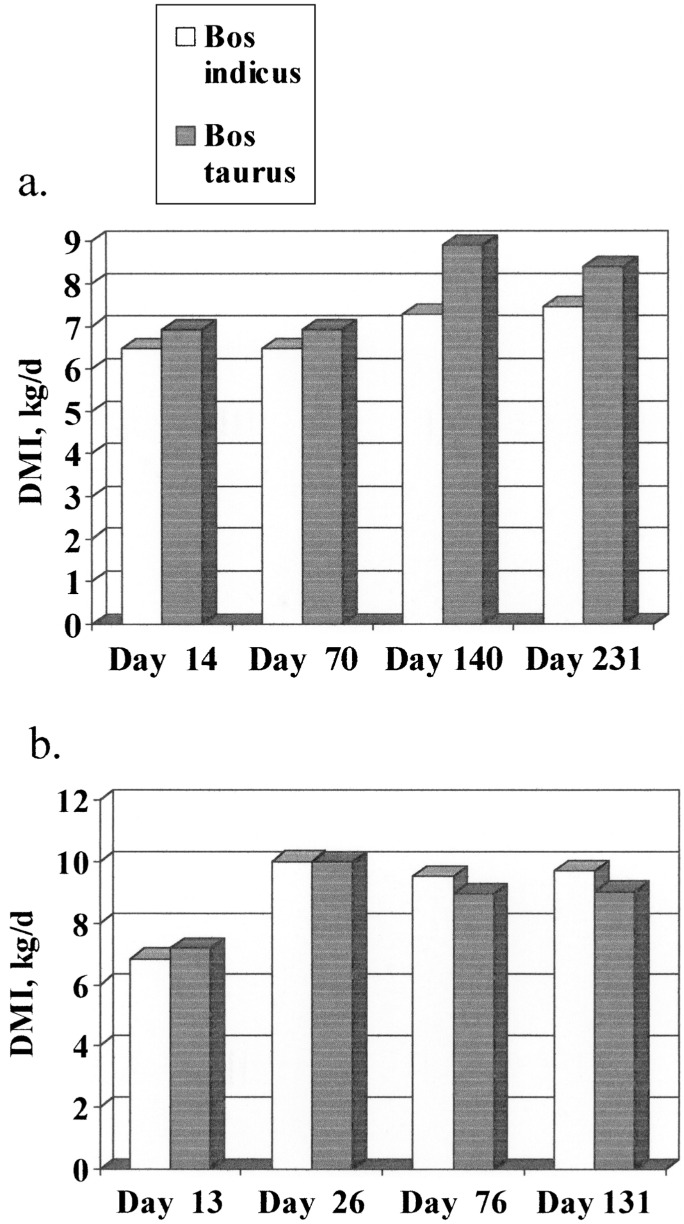

Figure 1. Effect of *Bos indicus* breeding on dry matter intake in calves (a) or yearlings (b). In calves, the biological type × day interaction was significant ($P < .01$). The pooled SEM = 1.56 for a and 4.31 for b.

total tract digestion of OM was not affected ($P > .05$) by biological type. In terms of digestibility, early research (Moore et al., 1975) indicated that purebred *Bos taurus* cattle were superior to purebred *Bos indicus* when the ration consisted of a concentrate mixture and the opposite was true when the feed was largely fibrous in nature. However, our data indicate that no difference exists in total tract OM digestibility between MARC III and *Bos indicus* × MARC III steers fed a high-grain diet. These results are supported by previous research with *Bos taurus* × *Bos indicus* crossbreds fed concentrate diets (Boyles and Riley, 1991; Colditz and Kellaway, 1972). In these experiments, total tract diet DM digestibility was similar between *Bos taurus* and *Bos indicus* × *Bos taurus* cattle. Boyles and Riley (1991) reported a mean diet digestibility of 82% in Angus steers compared with 74% in Brahman × Angus steers. However, these numbers were not significantly different ($P > .20$). Although site of digestion may differ among breeds, these data suggest that *Bos indicus* × *Bos taurus* cattle can digest high-grain diets as efficiently as straightbred *Bos taurus* cattle.

Similar to our results, Coleman and Evans (1986) reported no effects of cattle age on total tract OM digestibility of a high grain diet. However, in our experiment, apparent digestion of OM (grams/day) in the stomach was 33% greater ($P < .01$) in yearlings than in calves and tended ($P = .07$) to be greater as a percentage of OM intake (Table 3). As a percentage of OM intake, post-stomach OM disappearance was 48% greater ($P = .05$) in calves than in yearlings. Apparent total tract OM digestibility did not differ ($P > .05$) among treatments. These results indicate that more feed is digested in the rumen of yearlings than of calves consuming a high-grain diet. Similar to our results, Varel and Kreikemeier (1999) found greater ruminal OM digestibility in mature cows (522 kg of BW) fed high- or low-quality forage than in heifers (169 kg of BW). In addition, cows had greater ruminal OM fill (70 vs 52 g/kg of $BW^{.75}$), similar fluid fill (449 vs 456 g/kg of $BW^{.75}$), and greater liquid dilution rate (11.3 vs 7.8%/h) compared with heifers, respectively (Varel and Kreikemeier, 1999). The authors suggested that the faster ruminal fluid turnover might be responsible for a faster rate of ruminal digestion in cows vs heifers due to the removal of fermentation end products and the introduction of fresh fluid substrate. Bae et al. (1983) showed via multiple regression analysis that body size was the most important variable affecting rumination efficiency ($R^2 = .52$). Efficiency of chewing increased (i.e., less time required per unit intake) as body size increased. Similarly, Reinhardt et al. (1998) reported that reductive mastication of corn grain increased when calves were fed at a heavier BW (361 kg). Although data evaluating the effect of age on ruminal digestion of high-grain diets are limited, greater chewing efficiency and ruminal development and volume resulting from consuming high fiber through a growing period may explain the greater ruminal OM digestion in yearlings compared with calves.

We speculated that more OM fermented ruminally in yearlings than in calves would result in more microbial protein flowing out of the rumen. However, total N, microbial N, and nonmicrobial N flows at the duodenum did not differ ($P > .05$) among treatments (Table 4). More ammonia N flowed to the duodenum in yearlings than in calves ($P < .01$). Similar to OM, N digested in the stomach and fecal N excretion were greater ($P < .01$) in yearlings than in calves; however, as a percentage of N intake, no differences were observed. Post-stomach N disappearance was not affected ($P > .05$) by biological type or age of steers. Total tract N digestibility was 4% greater in calves than in yearlings, which was not significantly different ($P > .05$).

Duodenal flows of histidine (13.5 vs 9.5 ± 1.08 g/d, respectively; $P = .04$) and phenylalanine (22.3 vs 18.8 ± .7 g/d, respectively; $P = .02$) were greater in yearlings than in calves, whereas duodenal flow of lysine was greater (22.1 vs 18.3 ± .8 g/d, respectively; $P < .01$) in calves than in yearlings. A type × age interaction ($P = .04$) resulted because *Bos indicus* × MARC III yearlings had greater duodenal glycine flow than *Bos indicus* × MARC III calves (23.7 vs 17.8 g/d, respectively), whereas duodenal glycine flow in MARC III yearlings and calves was similar (20.5 vs 20.9 g/d, respectively). Total AA, essential AA, and nonessential AA flows to the duodenum were not affected ($P > .05$) by treatment (data not shown). Total ($P = .11$), essential ($P = .07$), and nonessential ($P = .12$) AA flows tended to respond with a biological type × age interaction. This resulted in *Bos indicus* × MARC III yearlings having greater duodenal amino acid flow than *Bos indicus* × MARC III calves, whereas duodenal amino acid flow in MARC III yearlings was similar to that in MARC III calves.

In summary, results of this experiment suggest that utilization of a high-grain diet is similar between *Bos indicus* × *Bos taurus* and *Bos taurus* cattle. *Bos indicus*

Table 3. Organic matter digestion in *Bos indicus* × MARC III and MARC III calves and yearlings consuming a high-grain diet

	Bos indicus × MARC III		MARC III			Probability[a]		
Item	Calves	Yearlings	Calves	Yearlings	SEM	Type	Age	T × A
OM intake, g/d	6,730	8,766	7,568	8,581	224	.43	<.01	.21
OM digested in the stomach								
Apparent, g/d	4,446	6,266	5,157	6,477	227	.23	<.01	.51
% of OM intake	65.8	70.8	68.3	75.1	1.6	.28	.07	.77
Fecal OM output, g/d	840	1,185	1,005	1,156	73	.53	.03	.37
Post-stomach OM disappearance, % of OM intake	21.8	15.7	18.4	11.5	1.5	.22	.05	.89
Apparant total tract OM digestibility, %	87.6	86.5	86.7	86.6	1.7	.72	.54	.59

[a]Probability corresponding to the hypothesis of no effect of biological type (T), age (A), or their interaction (T × A).

Table 4. Nitrogen digestion in *Bos indicus* × MARC III and MARC III calves and yearlings consuming a high-grain diet

Item	*Bos indicus* × MARC III		MARC III			Probability[a]		
	Calves	Yearlings	Calves	Yearlings	SEM	Type	Age	T × A
N intake, g/d	157	205	176	199	4	.45	<.01	.20
Duodenal N flow								
Total, g/d	80	96	90	90	4	.69	.15	.12
Microbial, g/d	57	69	70	68	3	.20	.31	.13
Nonmicrobial, g/d	23	27	20	22	2	.44	.51	.74
Ammonia, g/d	4.5	7.5	6.1	7.4	.5	.27	<.01	.19
N disappearing in the stomach								
Apparant, g/d	77	109	93	110	4	.30	<.01	.36
% of N intake	49	52	53	54	2	.24	.48	.80
Poststomach N disappearance								
Apparent, g/d	57	66	64	61	4	.83	.46	.15
% of Duodenal N flow	71	68	70	68	1	.84	.19	.98
Fecal N excretion, g/d	23	30	26	29	1	.52	.001	.23
Apparent total tract N digestibility								
% of N intake	85	85	86	86	1	.55	.87	.99

[a]Probability corresponding to the hypothesis of no effect of biological type (T), age (A), or their interaction (T × A).

crossbreeding did not affect daily gain, DMI, or feed efficiency, although quality grade was lower in *Bos indicus* × MARC III steers than in MARC III steers. The lack of response in performance is supported by no difference in total tract digestion of nutrients in *Bos indicus* × MARC III steers and MARC III steers. Cattle age resulted in more differences than biological type. Calves ate less feed and gained less weight but were more efficient than yearlings. Organic matter digestion in the rumen was greater in yearlings than in calves, whereas postruminal disappearance was greater in calves than in yearlings.

Implications

Our data suggest similar utilization of a high-grain diet by *Bos taurus* and *Bos indicus* × *Bos taurus* steers. Similar feedlot performance would be expected by *Bos indicus* crossbred and *Bos taurus* steers, although performance by *Bos indicus* crossbred steers may be greater in subtropical environments. In addition, no changes in duodenal flow of OM and N and greater postruminal disappearance of OM might result in calves being more efficient at utilizing high-grain diets than yearlings.

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